HUMAN SCHISTOSOMIASIS DUE TO *S. HAEMATOBIUM* IN SIERRA LEONE

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PLATE XIV

During December, 1923, and January and February, 1924, an investigation was carried out into the prevalence of human Schistosomiasis in certain districts of the Protectorate of Sierra Leone. A Report on the subject has been submitted to the Government of Sierra Leone and will be published in the *Annual Medical and Sanitary Report* of the Colony.

The Report dealt with :

1. The prevalence of Urinary Schistosomiasis in the various districts traversed, and among the various tribes examined.
2. The discovery of the intermediate snail host ; this was proved to be *Physopsis* c.f. *globosa*, Morelet.
3. The rarity of snails of the genus *Planorbis* and the absence of Intestinal Schistosomiasis.
4. Tribal customs which facilitate the spread of infection.
5. Sanitary condition of the villages.
6. Recommendations for the control of the disease.

In the present paper, it is proposed to deal with certain morphological observations on the cercariae found in the intermediate host, and with some facts relating to the bionomics of this snail which were not dealt with in the Government Report.

Major Connolly, to whom the various snails collected were sent and who kindly identified them, proposes to publish a complete account of all the snails found during the expedition and to include in it all previously known forms found in Sierra Leone.

DESCRIPTION OF THE CERCARIA OF *S. HAEMATOBIUM*

Examination. The snails were placed each in a separate small test-tube in clean water ; the cercariae which emerged were examined with a hand-lens of 20 magnification in order to study their movements. The fluid containing them was then pipetted off as required and mounted as a cover slip preparation, and the details of structure noted. It was found that cercariae which emerged just after clean water was added to the snails were more easily studied than those which emerged into water which had stood some time ; in the latter case the medium was not so translucent as in the former. The living preparation gave the most satisfactory results for the study of the suckers, the secretory glands and the excretory system, especially the flame cells. On the other hand, fixation with subsequent staining gave better results in studying certain features of the secretory gland cells and their ducts, the nervous system, the genital cells and cuticular spinulation. Specimens stained *intra vitam* were examined, the stain chiefly used being very dilute Leishman's stain.

Movement. In a tube of water the cercariae swim actively but intermittently ; as a rule, active progression is towards the surface of the water, the tail end leading. On cessation of swimming the furcal rami are usually held at right angles to the tail stem, and the animal begins to sink slowly. It was observed that if the rami were maintained at right angles (fig. 3, VI) the animal would quickly resume its upward movement towards the surface after a very short rest. If, on the other hand, the animal allowed the rami to curl inwards towards the tail stem in the shape shown in fig. 3, VII, it would fall rapidly in the water for a long distance. The downward movement was accelerated by curling the rami more tightly, until they appeared as two small knobs at the end of the tail stem.

Under a coverslip in a drop of water, the movements depend upon the amount of fluid ; if the fluid is deep the animal moves with great rapidity and passes out of the field. If the fluid is drained away slowly with blotting-paper, the animal attaches itself to the glass and progresses slowly by alternate protrusion of the cephalic end and drawing up after it of the body ; the tail, not being compressed by the slip, moves very actively at intervals ; it separates very easily from the body in such conditions and was observed to retain the power of independent movement for a considerable period, up to ten minutes after separation. This independent movement was most frequently slow, affecting chiefly the base and rami, but sometimes a very active lashing movement affecting the whole tail was observed; in no case was translatory movement of the separated tail seen. The separated body, however, is capable of active progression and in this the ventral sucker is strongly protruded and adheres to the glass surface. Occasionally the animal appears to have difficulty in releasing its hold by the ventral sucker and the anterior end of the body is turned so as to release the ventral sucker by the help of the anterior protrusible organ. During the various movements, the body alters its shape constantly and remarkably and the anterior protrusible organ is pushed vigorously against any obstacle; the margins of the ventral sucker appear circular, oval, or linear in different views.

The appearance of the moving body under a coverslip changes so rapidly and the shape of the important organs alters so completely from one moment to another, that it frequently has little resemblance to the diagram which is reconstructed to represent the animal; the attached tail undergoes equally great variations in appearance, even when moving fairly slowly. It is only when the animal's movements are slowed down by removal of fluid from under the coverslip that the more important organs can be studied, namely, the anterior and ventral suckers and particularly the secretory glands.

Measurements. It is extremely doubtful if the measurements of the length or width of the body and the tail and rami of such cercariae can have any other than a crude comparative value. This statement is based on the fact that the animal in the living state is capable of such remarkable variations in the size of its body, tail-stem and furcal rami. The states of contraction and extension which are so obvious in the living animal are represented in fixed preparations. While a general contraction of the animal may be the result of applying to it certain fixatives, the degree to which the contraction affects different parts of the body will depend on the state of those parts of the body at the moment of application of the fixative. This is illustrated in Table I, in which are given the maximum and minimum sizes of parts of the cercariae.

TABLE I

The maximum and minimum sizes (in μ) of different parts of the cercaria in specimens, living, or fixed in different ways.

Measurement	Part of cercaria	Living		Fixed in Schaudinn's fluid		Fixed in 5 % formalin	
		maximum	minimum	maximum	minimum	maximum	minimum
Length ...	Body ...	242	105	196	121	189	114
	Tail stem ...	253	186	232	147	228	136
	Furcal rami	92	80	77	44	94	52
Width ...	Body ...	92	35	80	58	70	40
	Tail ...	46	23	42	33	47	24

It is evident that a comparison of measurements which show such variation in the extremes under each method can have only limited value. Even if we take averages of one method of fixation, *e.g.*, 5 % formalin, it is of little advantage, because the averages may be deceptively alike for any two groups, while the individuals vary enormously. Thus, taking two sets of fifteen examples fixed by this reagent from among those for which the extremes are given above, the result shown in Table II was obtained.

TABLE II.

Showing the average measurements (in μ) obtained from formalin fixed specimens of *S. haematobium*.

	Average length in μ	
	1st set of 15	2nd set of 15
Body	144	144
Tail stem	184	177
Furcal rami	63	67
	Average width in μ	
	1st set of 15	2nd set of 15
Body	57	59
Tail	32	34

The statements of Soparkar (1921) with reference to the cercaria of *S. spindalis* that

'the fully extended body often measures twice the contracted,'

of Sewell (1922) with reference to *Cercaria indica* XXX that it measures in body length extended 210μ and contracted 90μ, bear out the statement of Cort (1919) with regard to *S. japonicum* cercariae, that

'measurements of the cercaria of *S. japonicum* are very unsatisfactory data for comparison.'

Measurements of *S. mansoni* cercariae given by Iturbe and González differ so considerably from those given by Faust (1919) as to support the contention that measurements are of little service in differentiating the cercariae mentioned. The difficulty of attaining any standard agreement in regard to the measurement of such organs as the suckers is as great as that attending the measurement of the body, tail stem and of the furcal rami.

Cuticle. On the body, tail and on the furcal rami are present small backwardly directed spines; these are present also on the ventral sucker, but were not seen on the oral sucker. The spines are longer and more sparsely distributed on the base of the tail stem; subcuticular muscles both longitudinal and circular are present and are strongly developed in the region of the ventral sucker. There are no eyespots.

Anterior sucker. This is of elongated oval shape with a definite, thick, muscular wall, and is capable of a considerable range of movement, chiefly extension and contraction. In the substance of the sucker there is a homogeneous looking mass of a semi-fluid consistency, in the posterior part of which there are numerous small oval cells. There is no evidence of the presence of a nucleus, or duct, or secretion which would entitle this body to be termed a gland analogous to the head gland described by the Japanese observers in the case of *S. japonicum* cercariae. The mouth aperture is subterminal and is usually seen as a small circular opening from which a tube leads backwards into the body. At the anterior margin of the sucker, considerably anterior to the mouth opening, are situated the openings of the secretory gland ducts. Each duct opens at the tip of a minute refractile spine out of which the secretion can easily be seen passing in living specimens. From this point the ducts can be traced backwards through the substance of the oral sucker, on its ventral aspect (fig. 2). There are five ducts on each side of the middle line. The ducts are markedly constricted where they pass through the wall of the oral sucker.

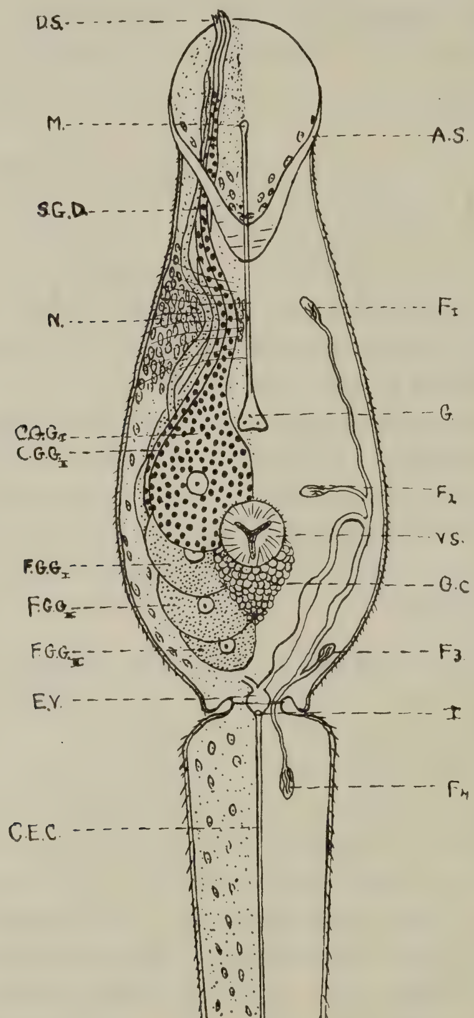

FIG. 1. Diagram of the Cercaria of *S. haematobium*. *D.S.*—Duct spines; *M.*—Mouth; *S.G.D.*—Secretory gland duct; *N.*—Nervous system; *C.G.G.*—Coarsely granular gland; *F.G.G.*—Finely granular gland; *E.V.*—Excretory vesicle; *C.E.C.*—Caudal excretory canal; *F.*—Flame cell; *A.S.*—Anterior sucker; *V.S.*—Ventral sucker.; *G.*—Gut; *G.C.*—Genital cells; *I.*—Island of excretory vesicle.

The Secretory Glands. The posterior two-thirds of the body are almost entirely occupied by pairs of unicellular glands. These glands in cercariae have received many names, *e.g.*, mucin, mucoid, poison, salivary, venom, lateral, proteolytic, cephalic, and secretory. Cort (1919) prefers to use the term ' cephalic,' since their ducts open at the anterior tip of the cercaria. As the term ' head gland ' is used by him for the gland in the anterior sucker of the cercaria of *S. japonicum*, this nomenclature is confusing. We use the term

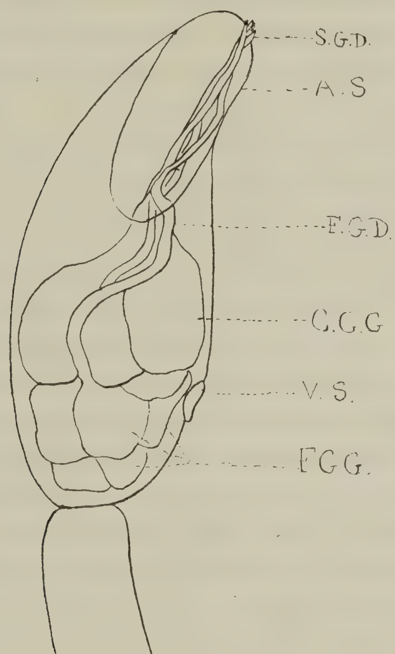

FIG. 2. Lateral view of cercaria of *S. haematobium*, drawn with the camera lucida, showing the course of the secretory gland ducts.

secretory glands for these body glands, in *S. japonicum.* The secretory glands number five on each side ; they are unicellular, each with a single nucleus and definite nucleolus. The protoplasm of the cells contains granules ; these are of large size in the anterior two pairs of gland cells, and small in the posterior three pairs of gland cells. The two pairs of anterior cells are large, generally flask-shaped, and lie about the same level, that is, just anterior to the ventral sucker. The three pairs of finely granular cells lie posterior to them ; they are of smaller size and overlap each other somewhat.

The ducts from the secretory glands pass forwards ; widely separated at their origin from the individual cells, they become approximated in the region of the nerve cells and separate again before entering the anterior sucker. The ducts from the coarsely granular cells are also coarsely granular throughout their extent in the body and for a short distance in their course in the oral sucker ; they lie more ventrally and closer to the middle line than do the other ducts. The division of these glands into coarsely granular and finely granular is a constant and easily recognised fact in the living specimen.

The affinities of these cells for stains are variable, Stained with eosin for a short time, the anterior glands and their ducts often take on the stain diffusely, while the posterior finely granular cells remain unstained. In formalin specimens stained for prolonged periods with eosin, not only the coarsely granular cells, but the finely granular cells and their nuclei are well stained. In specimens stained with Ehrlich's haematoxylin, the anterior coarsely granular cells remain as a rule unstained and appear as a clear area in front of the ventral sucker, whereas the posterior finely granular cells with their ducts are deeply stained. With iron alum haematoxylin, the nuclei of the secretory gland cells both anterior and posterior are well defined and can be easily counted on careful focussing. The results obtained by staining were, however, not constant, even in fully developed cercariae. It is possible that the staining affinities of these glands vary to some extent with variation in their state of secretory activity. Faust and Meleney (1924) state that in the case of *S. japonicum* cercariae—in which the cephalic glands are all of one type—these glands are basophilic in reaction in very young cercariae. On reaching maturity the reaction changes from basophilic to oxyphilic, which condition prevails in the mature cercaria. Cort (1919) describing the same glands also in the cercaria of *S. japonicum*, states that they are stained a light blue with haematoxylin. It is interesting to note that the head gland of *S. japonicum* cercariae is described by Cort (1919) as taking ' the red stain erythrosin,' while Faust and Meleney (1924) state that it is slightly basophilic. Enough has been said to show that the acidophilic or basophilic character of these cells is not a sufficiently definite nor stable one to justify its use as a distinguishing specific feature.

Alimentary Canal. This is simple in type and consists of a straight, narrow tube which passes from the mouth posteriorly and dorsally and ends in a small heart-shaped dilatation ; there is no pharyngeal bulb.

Excretory System. This commences in four flame cells on each side ; three of these are situated in the body as follows :—The anterior one half-way between the anterior extremity and the ventral sucker, the middle one on a level with the anterior margin of the ventral sucker, the posterior one about the level of the most posterior of the secretory glands. The fourth flame cell is situated in the tail near the base (fig. 1). From each flame cell a capillary leads off ; those from the anterior and middle body flame cells join ; those from the tail and posterior body flame cells also join. The two collecting tubes so formed unite at the level of the ventral sucker, curve ventrally and then pass towards the junction of the tail and body. Here they enter a globular excretory vesicle. From this a tube arises posteriorly which runs down the centre of the tail stem ; it divides into two branches just above the tail fork and each branch passes down one furcal ramus to open at its tip in a definite papilla. The flame cells in the body are seen most clearly from the dorsal aspect.

The excretory system corresponds closely with that of the cercaria of *S. japonicum* described by Cort and with that of *Cercaria indica* XXX described by Sewell. Cort (1919) found in addition ' two ciliated areas on each side near the ends of the sides of the bladder ' Sewell (1922) found two dilatations on each canal, each dilatation being provided with a ' flagellum.' The position of the flagellum in *cercaria indica* differs from that of the cilia in the cercaria of *S. japonicum*, as shown by the diagrams. We have not been able to satisfy ourselves of the presence of any flagellated or ciliated area in the collecting tubes of *S. haematobium.* In one specimen under observation from the lateral view, an appearance was noted which suggested the presence of such an area, but on rolling the specimen slightly it was found that the flickering movement seen was due to the movements of the flame cells of the opposite side showing through the body protoplasm.

Genital System. A triangular shaped mass of small cells just posterior to the ventral sucker represents the genital system.

Nervous System. There is in the region behind the anterior sucker a mass of cells which is wide at the lateral margins and tapers rapidly to cross the middle line as a narrow band ; in the substance of the mass, faint transverse lines are seen ; this appears, from analogy with other cercariae, to be the precursor of the nervous system of the adult.

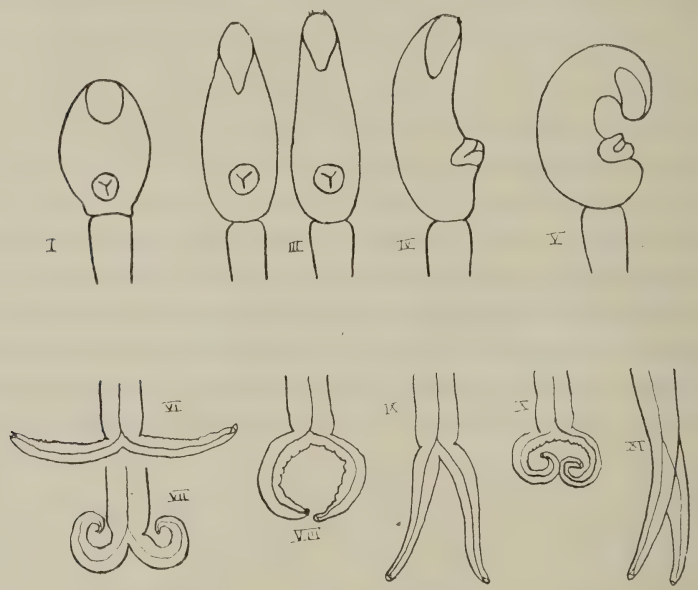

FIG. 3. Diagrams illustrating various positions assumed by the cercariae of *S. haematobium.*

The Ventral Sucker. This is small, being less than half the diameter of the anterior sucker. It is situated on the posterior fourth of the body. Its most characteristic feature is the remarkable degree to which it can be protruded. Seen from the side it has a cup-shaped appearance while from the ventral aspect it appears as a muscular ring with radiating lines and a central Y-shaped aperture. It is used by the animal for attaching itself to objects ; the anterior sucker is used freely as a penetrating organ.

THE DIFFERENTIAL CHARACTERS OF THE CERCARIAE OF THE THREE HUMAN SCHISTOSOMES

It has been shown that in the Schistosome cercaria from Sierra Leone here described, there are two sets of secretory glands comprising two with coarse granules and three with fine granules on each side of the body. The number, morphology, and position of the secretory glands in this cercaria are such as to distinguish it definitely from the cercaria which Faust describes as that of *S. haematobium*. On the other hand it agrees somewhat more closely, in the secretory gland arrangement, with his description of *S. mansoni*. He describes, however, six pairs of ' mucin glands ' for the *S. mansoni* cercaria. In the number of glands the Sierra Leone cercaria agrees with the number for *S. japonicum* given by Cort ; it differs in having the glands divided into coarsely and finely granular cells.

Faust (1919) gives the following table :—

TABLE III.

Diagnosis of Species of Human Schistosome Cercariae.

	S. haematobium	*S. mansoni*	*S. japonicum*
Size (in μ) :			
Body	240 × 100	140 × 60	100 to 210 × 66
Tail trunk ...	200 × 47	200 × 27	150 × 20
Furci	80 to 100 long	50 long	75 long
Oral sucker ...	60 in transection × 64 in length	30 to 34 in transection × 30 to 34 in length	33 in transection × 54 in length
Mucin glands ...	3 pairs with large nuclei and granular acidophilic cytoplasm.	2 pairs with large nuclei and granular acidophilic cytoplasm ; 4 pairs with small nuclei and basophilic slime contents.	5 pairs with large nuclei and granular acidophilic cytoplasm.
Mucin ducts ...	Moderately thick.	Very thick.	Very thick.
Duct openings ...	At anterior end of oral sucker ; capped by 3 pairs of hollow piercing spines.	At anterior end of oral sucker ; capped by 6 pairs of hollow piercing spines.	At anterior end of oral sucker ; capped by 5 pairs of hollow piercing spines.
Germ cells	Several large cells posterior to acetabulum	Many cells at posterior end of body	Clustered mass of cells just behind acetabulum
Parthenita	Sporocyst	Sporocyst	Sporocyst

Let us now consider these diagnostic points individually. Reasons have already been given for doubting the value of the *measurement* criterion.

The thickness of the *mucin ducts,* which are described by Faust as :—*haematobium,* moderately thick, *mansoni,* very thick, *japonicum,* very thick, can have no significance, because, as has been shown, the ducts of the secretory glands of the cercaria undergo great and definite variation in thickness at certain points during their course forwards to the cephalic extremity. The *duct openings* correspond in Faust's table to the number of glands allotted by him to each species ; they are each capped by a hollow piercing spine, and are situated at the anterior end of the oral sucker. The description of the position and number of the *Germ cells* given is not such as to afford much assistance in diagnosing the three species, nor is it of help in allocating the present cercaria. 'Several large cells posterior to acetabulum,' 'many cells at posterior end of body' and 'clustered mass of cells just behind acetabulum' may represent very similar numbers and arrangement of the Germ cells. The *Parthenita* in all cases is Sporocyst. It is seen therefore on analysis of this Table that the supposed differences which are set out so far are indeed trifling and are valueless for diagnosis. Only in one particular, namely, the number and character of the *mucin glands,* does there appear to be a point of some value—*haematobium* three pairs, *mansoni,* six pairs, and *japonicum* five pairs.

It is legitimate at this stage to examine the basis upon which this diagnostic table was compiled. The most complete description of the cercaria of *Schistosoma japonicum* then existing was that of Cort (1919). When Leiper (1915) differentiated by experimental means the two forms *S. haematobium* and *S. mansoni,* he did not give any such detailed account of the cercaria as has since been attempted, for he considered that animal experiment gave the only satisfactory differentiation.

Faust (1919) studied specimens of cercariae from Natal believed to be those of *S. haematobium* and gave a description which is too long for complete quotation.

'The oral sucker leads into a digestive tract without any evidence of a pharynx. An oesophagus runs backwards into *ceca which extend about three-fifths the distance caudad* (italics not in original). Paired groups of mucin glands empty their slimy contents at the outer margin of the oral sucker. Each duct opens thru' a hollow piercing spine which caps the duct. Each group can be traced back to three mucin glands in the region of the acetabulum. These cells have loosely scattered granules in the cytoplasm and large nuclei. No other mucin glands have been found. Several germ cells have been found in the region of the body posterior to the acetabulum. The number is considerably in excess of the number of testes in the adult worm.'

This description, it will be observed, was made from dead material sent by Dr. Cawston; the material also contained cercariae which Faust described as those of *S. mansoni*.

There are certain facts of great relevance which may be brought into evidence with regard to the description of *S. mansoni* given by this author. He examined specimens of *S. mansoni* cercariae from Caracas and found that

'the mucin glands consist of only two pairs of cells of the granular type, but, in addition, four pairs of a non-granular type, somewhat smaller and surrounding the granular cells.'

This description is markedly at variance with that given by Iturbe who figures the glandular system of *S. mansoni* as having only three glands on each side. Faust (1920) states that

'this method of distinguishing between these species of larvae makes it possible to diagnose two species in material which Dr. F. G. Cawston has sent the writer from Natal, namely, cercariae of *Schistosoma haematobium* and those of *S. mansoni*. The latter species corresponds both by structural and micro-chemical tests to Iturbe's species from Venezuela.'

When we pursue this matter a little further, we find that Cawston (1920) is of the opinion that 'the statement must be taken with caution.' Later Cawston (1922) makes further reference to this subject and to Faust's diagnosis, as follows:

'In a specimen of *Physopsis africana* which I sent him from Natal, Faust has reported the presence of the cercariae of *S. haematobium* and *S. mansoni*, as well as *Cercaria octadena* which he regards as a developmental stage of *S. bovis*—it is difficult to understand how one individual snail from the Durban suburbs can have been exposed to infestation by the miracidia of all three Schistosomes.'

Faust (1921) met this criticism in so far as *S. mansoni* was concerned by pointing out again that the cercaria described by him for South Africa corresponds in all critical points with his description of the one from Venezuela which is known experimentally to be the larva of *S. mansoni*. Some explanation of this kind was clearly demanded as Cawston had drawn attention to the curious fact that although *S. mansoni* infection in human beings was not known to him to occur endemically in Natal, yet a single specimen of a snail harboured the cercaria of *mansoni* as well as that of *haematobium* and of *bovis*. Further there was the additional cause of surprise to Cawston that the cercaria discovered in such interesting circumstances should be found in a type of snail host, *Physopsis africana*, which was never previously reported to contain the cercariae of S. *mansoni*. Faust would certainly appear to have been fortunate in obtaining in one snail specimen no less than three distinct species of schistosome cercariae and the fact that two of these were of great importance as being the early stages of Schistosomes affecting human beings gave his findings additional weight. The discovery by this means of the hitherto unsuspected endemic existence of S. *mansoni* in Natal was possibly of great epidemiological significance. Incidentally the revelation of a new type of snail intermediate host for S. *mansoni* was not less striking.

We find then that Faust's description of the cercaria of S. *haematobium*, is based on no definite evidence that he was in fact dealing with the cercaria of this species. It was not proved experimentally to be associated in any way with S. *haematobium*. The only evidence that it might probably be the cercaria of this adult worm was that it came from a likely snail from an endemic area. But the very fact that it came from a snail which was an intermediate host of S. *haematobium*, appeared to Cawston somewhat strong evidence against there also coming from this snail a cercaria which was the young stage of S. *mansoni*. In 1921 Faust, to meet the objections of Cawston, and in order to clinch the argument finally, made the following statement with regard to the same snail :—

> 'Furthermore, I have actually seen the lateral spined eggs of S. *mansoni* preserved in the liver gland of *Physopsis africana* which Dr. Cawston collected from Ottawa, Natal, and later sent me.'

Faust does not suggest any possible or probable explanation as to the means by which these eggs arrived in the position stated in the snail.

Thus detailed descriptions of cercariae which he presumed were those of S. *haematobium* and S. *mansoni* have been made by Faust ; in both cases from preserved material and without the advantage of studying living material. The great necessity of examining living specimens is emphasized by Cort, Sewell, Soparkar, and others who have added materially to our knowledge of the minute anatomy of cercariae.

THE IDENTITY OF THIS CERCARIA FROM SIERRA LEONE

We are faced by the fact that the description of the cercaria as given above differs from the description of the cercaria of *S. haematobium* given by Faust and reproduced in various text-books. It differs from his description not only in the number and character of the secretory glands but also in the anatomy of the alimentary canal. If this author's description is correct, then we are dealing here not with *haematobium* but with some other species. But the evidence provided by the epidemiology, by the experimental infection of snails, by the type of snail infected, and last of all by the results of the experimental infection of laboratory animals appears too convincing to be set aside, and we have little doubt that this cercaria is, in reality, that of *S. haematobium.*

The evidence which can be given to prove that it is the cercaria of *S. haematobium* is :

A. Incidence in Human Host.

Among the population examined no schistosome ova other than those with terminal spines were found. In a total of 180 faeces examinations these ova were found once ; among a total of 808 urine examinations they were found in 305 persons.

B. Experimental Infection of *Physopsis* c.f. *Globosa*, Morelet

Nine specimens of this snail from an uninfected area were kept in separate tubes and examined daily. Each day fresh water which had been boiled and then allowed to cool was used to replace that in which the snails were kept. The snails did not give out any cercariae ; controls which were dissected did not show any infection. The terminal spined ova from the urine of an infected case were then added to the tubes in which the snails were kept, on two successive days. Active miracidia were seen attaching themselves to the snails. The water thereafter was daily examined as before and then changed when found free of cercariae. On the fifteenth day after the second exposure, cercariae were found in the water in which one of the snails was. Two others also were found to be infected during the next examination. Dissection of the remainder of the snails did not reveal any others infected. The cercaria found in the case of each of these snails was identical with the cercaria described here from naturally infected snails. This experiment is of course open to very obvious objection if it were the only evidence provided, but as purely corroborative evidence it has some value. It is of interest to note that the cercariae from one of these snails were used to infect a monkey and that from this animal the adult male form of *S. haematobium* was recovered.

C. Incidence in Snail Host.

Planorbis (*Hippentis*) species was found in only one village out of 30 examined, and of 318 specimens dissected none harboured this cercaria, although 151 were infected by cercariae of other kinds.

The snail here found associated with the presence of the disease in human beings was this *Physopsis* sp., nearly akin to *Pl. globosa*, Morelet. This was also the only snail found infected with the cercaria described. The infection rate in these snails with this cercaria was frequently high and was particularly so when the snails were taken in water latrines; in one case 42 per cent. of 50 snails taken in such a site were infected with this cercaria.

D. Experimental Infection of Laboratory Animals.

From guinea-pigs and monkeys which were submitted to scanty infection with this cercaria by feeding, adult males morphologically identical with *S. haematobium* were recovered after a period of three months.

Such is the evidence which makes it probable that this cercaria is that of *S. haematobium*.

Reverting now to the differential characters given in Table III it appears that the only one which seemed to be definite has broken down in so far as concerns the cercaria of *S. haematobium* and that we are left with very little upon which to base a diagnosis between the three species of cercariae which affect human beings. The gland arrangement in *mansoni* will doubtless receive further attention and should it be proved from careful study of living specimens that the cercaria of *S. mansoni* possesses five glands on each side, then we shall have reached again the stage at which, pending the production of further morphological facts or other criteria, we must diagnose the cercariae by the experimental method.

Bionomics of *Physopsis*.

Some observations which appear worthy of recording were made on this snail. The snail was found only in certain situations; in water which lay or ran slowly on a muddy bottom, where weed or grass grew in the water, and under high or low shade; it appeared that these three factors—mud, weed, and shade—were essential to it in the water of the localities in which it was found (Pl. XIV, figs. 1 and 2). It was never found in a stream which had a clean sandy bottom, even though weed and overhead shade were present. Further, it was often absent in places which looked at first sight admirable sites for it, in water that is to say with shade, mud and weed; examination proved that the mud layer at the bottom of the water in these places was only a thin layer lying over sand. This snail likes mud, and the mud-living habit doubtless explains its distribution in the country traversed. In the hilly country, the stream bottoms were covered with sand, and there was no silting of mud. Consequently, this snail was not found at the villages situated round the base of the Loma mountains. Indeed, in the mountainous Koranko country, it was only found on the route traversed at two places. Sokurella and Benikorro, both in relatively low lying country. Its habitat is important from the point of view of prophylaxis against Schistosome infection. It may be mentioned that it was found in large numbers in a wet rice field at Jiama, which was practically marsh land; on the other hand it was never found in open, quickly flowing streams, in the same locality.

Infection of *Physopsis* with Cercariae of Human Schistosomes

Of 1557 specimens of *Physopsis* dissected, 306 had cercariae of some kind present in their tissues. Out of the 306 there were 184 infected with the cercariae of *S. haematobium* which was, as shown above, the only Schistosome affecting the population examined. In some cases where cercariae of *S. haematobium* were found, other cercariae were also present in the same snail. On the other hand, in snails from some localities, little or no infection of any kind was found ; the variable rate of infection from different localities was a very striking phenomenon. Examples of this are given in Table IV in order of increasing infection.

TABLE IV.

Giving infection rates in *Physopsis*

Locality	Number of *Physopsis* dissected	Number infected with cercariae of *S. haematobium*	Percentage
Jiama (Nimmi Yemma)	497	12	2·4
Jiama (Nimmi Korro)	200	18	9·0
Bendu	160	18	11·2
Taiko	48	8	16·6
Kaiyima	373	112	30·0
Paya...	50	21	42·0

These high rates of infection in *Physopsis* may be compared with the figures which are given by Manson-Bahr and Fairley (1920) for *Bullinus* in Egypt. These authors discuss the reasons which may account for the fact that while it is difficult to find *Bullinus* infested in any numbers, the infestations of human beings with *S. haematobium* are very numerous. They point out that the highest infestation recorded by them in this snail for one month was 9 per cent., and that it more commonly was 1 or even less, per cent.

On considering the factors which result in the production of a high rate of infection in these snails, we found that the infection rate was directly proportional to the contamination of the water supply in a village by human excreta. The effect of even a small stream, if used for latrine purposes, in producing a high infection of *Physopsis* with cercariae of human Schistosomes is clearly seen on analysing the Jiama (Nimmi Yemma) figures. One section of the village goes to a spring for its drinking water. The path to this spring passes through a shallow, muddy pool into which comes the water from the men's latrine situated a few yards away (see fig. 4). From the spring a stream runs towards the village and turns sharply into a wet rice-field just before reaching the pool mentioned. The spring and the upper part of the stream from it yielded no *Physopsis ;* the water ran on a bed of coarse sand. Lower down towards the village a layer of mud had formed on the sand and one *Physopsis* was found here. On following this stream into the rice-field where it became

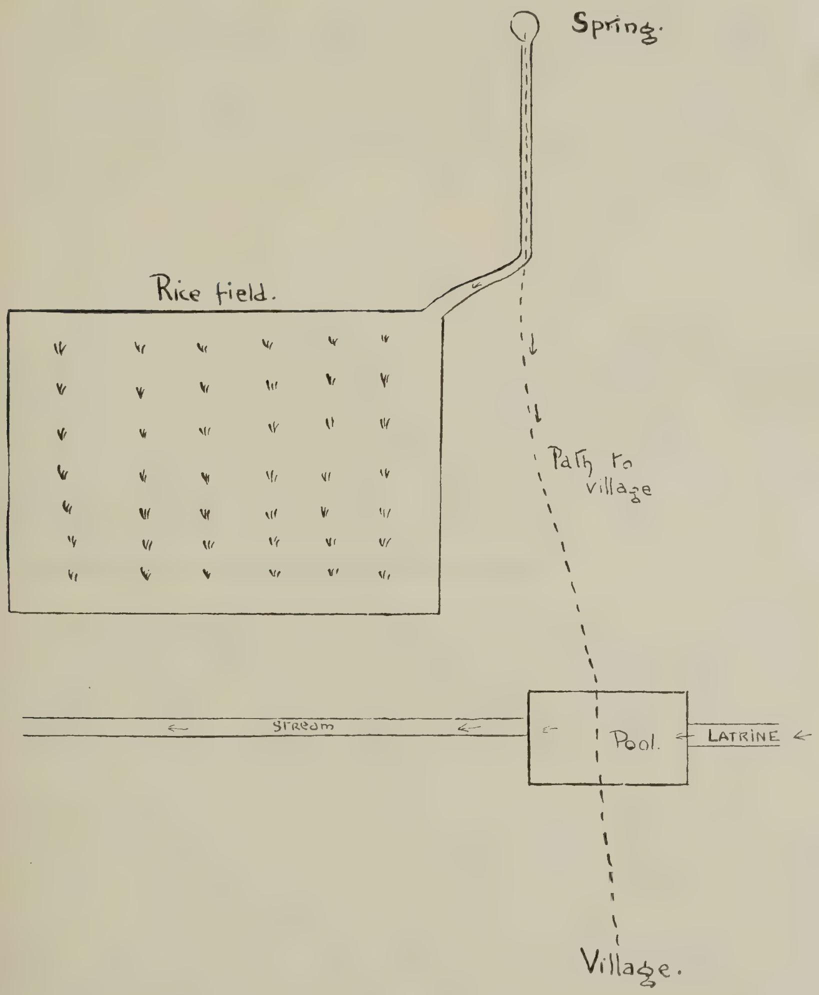

FIG. 4. Diagram of Spring, Rice-field, and Latrine pool at Jiama.

lost in marshy muddy ground, *Physopsis* was easily found, usually on weeds or on the underside of fallen leaves ; many were in the mud and came to the surface after the mud had been trampled down.

In the pool adjacent to the latrine (see Pl. XIV, fig. 1) *Physopsis* was also found ; the pool water did not enter the rice-field but skirted alongside it for some distance. The result of dissection of snails from these different sources is illuminating, and is set out in Table V.

Table V.

Cercariae of *S. haematobium* found on dissection of *Physopsis* at Jiama (Nimmi Yemma).

Source	Number of *Physopsis* dissected	Number infected	Percentage
Rice field	430	1	0·2
Stream	1	0	0·0
Pool adjacent to latrine	66	11	16·6

The present position at this corner of the village is that every one in going to fetch water from the spring has to wade through a pool of water which is a veritable sewer and contains highly infected snails. This pool is an ideal one for the dissemination of cercariae since most children in passing through the water play about in it for some time. Situated in such favourable circumstances, the infected snail is able to do the greatest damage to the maximum number of people.

The facts noted here were confirmed almost immediately in the case of two villages in the vicinity, Paya and Taiko ; from each of these villages people had come for treatment. As a return they were asked to collect snails. The instructions given were that they should go to the place where the men's latrine was and search the water there. The results were :—from Paya, 50 *Physopsis* of which 21 that is 42·0 per cent. were infected with cercariae of *S. haematobium ;* from Taiko, 48 *Physopsis* of which 8 that is 16·6 per cent. were similarly infected. A messenger was next sent to Jiama (Nimmi Korro) with identical instructions. He returned 29.12.23 with nearly 300 *Physopsis* of which 200 dissected yielded 18 infected with human cercariae, that is 9 per cent. It is of interest to note that the pool at Jiama (Nimmi Korro) in which these snails were found, dries up in the dry season. A messenger sent there in April found only 6 *Physopsis* alive in the mud at this particular spot.

Physopsis then, in addition to being a mud snail here, is also quite definitely a sewage snail, and that to a very marked degree. It was observed that those *Physopsis* from the water latrines were the largest and most active of all found, as well as being the most heavily infected with human Schistosome cercariae.

The fact that at Jiama the latrine snails were relatively few but heavily infected, while a few yards away the rice field snails were many and scantily infected, is one which may prove of considerable importance from the practical point of view. It is evident that a comparatively simple modification of the latrine arrangements of such villages should result in a great diminution of human Schistosomiasis.

Resistance of the *Physopsis* sp. to Drying

Experiments were made in order to ascertain to what extent the snails could survive alterations in their environment, especially by drying. The appearance of the snails after comparatively short periods of drying is deceptive ; the animal retracts very far into the shell and looks as if it were dead, but on immersion in water it expands slowly and resumes activity.

(1) Alternate Drying and Soaking

5 snails were placed dry in a glass dish in the shade. They were kept thus for a period of 20 hours and then placed in water. After 4 hours in water the whole process was repeated. All 5 snails survived 2 days of such treatment, and 3 survived over 3 days.

(2) Drying

2 snails glued on a card were exposed alternately to sun and shade for 48 hours. They were still alive, and moved actively after soaking for an hour-and-a-half in water.

3 snails were tied in dry muslin and placed in the shade. After 3 days they were put in water. 1 was alive. This one was subjected to alternate drying and soaking as in the first experiment. It survived until the 9th day.

5 snails were tied in dry muslin in shade. After 3 days 3 were alive ; dried and tested again on the 5th day, 3 were still alive ; on testing on the 7th day they were dead.

(3) Gradual Drying on Mud

18 snails were placed on wet mud in shade and the water was gradually drained away from the vessel. The snails remained on the surface of the mud adhering to it and retracted within their shells. On the 13th day all the snails were placed in water. After a long period 14 were alive and active. The first showed signs of life only after over an hour's immersion, and the last only after 10 hours immersion.

Depth in Soft Mud attained by the Snails

Many experiments were made to see whether exposure to sun on wet mud or on drying mud would cause the snails to bury themselves. In only one case did a snail go so deep as an inch-and-a-half from the surface, in the vast majority of cases they remained either on, or just under the surface. Direct sunlight was rapidly fatal to snails lying on dry mud.

These experiments prove that the resistance of this snail to various alterations in its environment is by no means negligible. It appears to be a much more resistant snail than *Isodora innesi* of which Archibald (1923) writes : 'if deprived of water for a period longer than six hours, it will surely die.'

The practical importance of the possession of such resistance by this *Physopsis* sp. is that merely cutting off or diverting the water for a few days in infected areas will not ensure the death of all or probably even of many of these snails.

It is of interest to note that in describing the present day conditions of the village of El Marg in Egypt, Faust and Meleney (1924) remark :

'as in the past the water supply was intermittent, being off for five days then on for a period. Snails of the species *Isodora truncata* were collected just north of the village. Leiper's (1915) recommendations have apparently not been carried out.'

One conclusion in the Report to the Government, arrived at as a result of the consideration of the local conditions, was that the proper and only promising methods of dealing with the problem of Schistosomiasis here was firstly by means of attacking the snail where it is known to be infected, and secondly, by so modifying, through education, local customs with regard to water pollution, as finally to prevent infection of snails. Any attempt here at an extensive and wholesale campaign of treatment by antimony or other drugs was deprecated as being, for definite reasons given, likely to defeat its own object and to be an expensive failure.

SUMMARY

(1) During an investigation into the prevalence of Schistosomiasis in certain districts of the Protectorate of Sierra Leone, infection due to *S. haematobium* was the only type of the disease found.

(2) *Physopsis* c.f. *globosa*, Morelet, was proved to be the intermediate host ; the infection rate in the mollusc with cercariae of *S. haematobium* was often very high, *e.g.*, 42 per cent. in a water latrine.

(3) A description is given of the morphology of the cercaria of *S. haematobium ;* it differs markedly from the description of this cercaria at present accepted.

(4) A critical analysis of the basis of the existing description is undertaken.

(5) Some facts relating to the bionomics of *Physopsis* c.f. *globosa* are mentioned ; experiments showed that this snail was resistant to drying to an unexpected degree.

(6) Of snails placed on mud in the shade a large percentage survived for a fortnight when the water was drained away gradually.

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EXPLANATION OF PLATE XIV

Fig. 1. View of latrine pool at Jiama. (*Vide* fig. 4). Infected *Physopsis* found.

Fig. 2. View of washing and latrine pool at Kaiyema. Infected *Physopsis* found.

Fig. 3. View of men's bathing place on the River Kaiso. No snails found. Sandy bottom, no shade, quickly flowing.

FIG. 2

FIG. 1

FIG. 3

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